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ABSTRACT

Academic learning experiences provided during a unit on genetics were examined in this case study report of two honors biology classes. It was conjectured that the nature of students' work and how it is handled by teachers affects how students attend, how they process information, what skills they practice, how they are evaluated and ultimately what they learn. Specific questions that were investigated include: (1) how did the teachers translate their knowledge of the content and curriculum into sets of learning tasks; (2) how were the tasks managed by teachers and accomplished by students; (3) what were the effects of the teachers' task decisions on the kinds of learning experiences students had with the content; and (4) what opportunities were available for learning genetics concepts. Classroom tasks and relationships between tasks and other aspects of instruction were analyzed and problem areas in task management were identified. The interviews, analyses of student performance on quizzes, and interactions during class provided evidence that there was poor student understanding of concepts and procedures in several specific areas. Findings further suggested that teachers need to make careful choices in planning classroom tasks and in maintaining a balance between curricular demands and classroom needs. Tables showing sequence of task content in the two classrooms and summarizing genetics unit tasks for each teacher are appended. (ML)

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Teaching and Learning Genetics:

Case Studies of Academic Work in Two Classrooms

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Teaching and Learning Genetics:
Case Studies of Academic Work in Two Classrooms

This study examined academic work in two high school biology classes which were included in a broader study of the management of academic tasks in secondary schools (Doyle & Sanford, 1985; Doyle, Sanford, Nespor & French, 1985). Analysis focused specifically on the learning experiences students in these two classes had during entire units on genetics. Analysis of classroom tasks and relationships between tasks and other aspects of instruction resulted in identification and illustration of problems in task management and presentation that are faced by all secondary science teachers and that in these cases limited students' learning experiences with genetics content.

Background and Objectives

Genetics was selected as the content for this study of work in high school science classrooms because it is an important part of the first year biology curriculum but one that appears to be difficult for teachers and students. Studies of student concept learning in genetics suggest classroom instruction is often ineffective.

For example, Hackling and Treagust's (1984) interviews with students from 13 Australian classrooms showed that after instruction the majority of the students failed to understand half of the propositions critical for comprehension of the topic. The researchers interviewed 48 students from six schools, probing for understanding of 18 essential propositions. Students were required to apply their understanding of the concepts and propositions in explaining novel situations. Apparent

misconceptions were identified and responses coded as recall or comprehension levels. Results showed that close to half of the propositions were comprehended by fewer than 25% of the students.

Major difficulties experienced by students in the Hackling and Treagust study included comprehension or application of ideas involved in the separation of chromosome (and gene) pairs at meiosis and their recombination during fertilization. Students also frequently failed to comprehend the role of probability or chance in genetic transmission. The authors attributed these difficulties in part to students' lack of ability to utilize formal reasoning, an interpretation they felt was consistent with research indicating that large proportions of 10th-grade students are limited to concrete operational thought.

Stewart and Dale (Stewart, 1983; Stewart & Dale, 1981), on the other hand, suggest lack of explicit instruction on conceptual relationships, rather than lack of formal reasoning abilities, as a source of student errors in genetics problem solving. They conducted interview studies in introductory high school biology classes in midwestern schools. Students were required to solve mono- and dihybrid genetics problems as they explained their reasoning behind manipulations made. Many students were able to execute procedural steps of the problems correctly without demonstrating an understanding of the underlying conceptual knowledge. A lack of problem-solving experience and explicit instruction concerning these conceptual relationships was suggested as a major source of difficulty experienced by students. In support of their hypothesis, the authors cited an experiment in which a student who had demonstrated initial poor conceptual knowledge of genetics and related problem solving was tutored for three 40-minute

sessions following classroom instruction on the content. The tutoring sessions included practice problem solving and explicit instruction concerning conceptual relationships of relevant concepts. In a final problem-solving interview, this student was able to solve genetics problems successfully, providing accurate information regarding the reasons for manipulations made. Thus the Stewart and Dale studies, rather than questioning the suitability of inclusion of genetics content in the 10th-grade science curriculum, suggest that the nature of instruction and opportunities for practice are critical.

Genetics is by no means the only science topic area in which teaching and learning problems have been demonstrated. Research suggests that classroom instruction is often ineffective in changing students' conceptions of important science phenomena. A large number of studies (see, for example, Helm and Novak, 1983) have demonstrated that many elementary and secondary students receive instruction, perform experiments and engage in problem solving activities without gaining a good understanding of the work or concepts.

Surveys and observation studies of science classrooms provide some clues about why learning problems persist in many secondary classes. Large scale studies (Boyer, 1983; Weiss, 1978) indicate a predominance of classrooms with a text-bound curriculum emphasizing recall-level objectives, with few opportunities for students to develop higher order thinking or inquiry skills. In a report of a qualitative study of instruction in fifteen Australian high school science classes, Tobin (1985) presents a picture of teaching dominated by pressures to cover large amounts of complex content, dictated by the syllabus, in small amounts of time. Poor articulation was seen between laboratory

activities and the rest of classroom content and activities in grades 8 through 10, and in upper high school courses little laboratory work was used. In all grades studied cognitive level of academic work was often reduced by allowing students to copy information from books without demonstrating understanding of it or developing generalizations. Also, teachers provided students with "type examples, algorithms and rules of thumb," routinizing content until students could often provide correct answers to problems without understanding the scientific principles. A heavy emphasis on complex terminology was noted. Overall, Tobin describes an emphasis on completing programmed work in the available time rather than on insuring that students develope depth of understanding, and a lack of apparent concern for students' developing concepts about science in the world outside of the classroom and the textbook.

Objectives

With the above-described research as background, a systematic examination was undertaken of the academic work in genetics units in two classrooms taught by experienced teachers. Information obtained prior to teacher selection indicated that both teachers had a good understanding of the content and high school curriculum goals and that their teaching focused on helping students to make sense of the content (to understand the concepts and be able to apply them in their daily lives). Further, both courses were designed for higher achieving students and had explicit, stated objectives of developing students' higher order thinking skills. Thus the two classes provided opportunities to examine interactions and conflicts between the demands of the classroom environment and the demands of the curriculum.

Focusing on classroom work provided a framework for assessing students' learning opportunities with this content. Specifically, the questions guiding our data collection and analysis were:

1) How did each of these teachers translate their knowledge of the content and curriculum into sets of learning tasks for students?
2) How were these tasks managed by teachers and accomplished by students?
3) What were the effects of the teachers' task decisions on the kinds of learning experiences students had with the content? What kinds of opportunities did students have for learning genetics concepts?

Why Focus on Academic Tasks?

This study used an adaptation of the academic task model formulated by Walter Doyle (1983). This model calls attention to the work that students do and how that work is presented and managed by teachers. Focusing on work allows us to examine simultaneously several of the most important dimensions of science classrooms: teachers' planning and instruction practices, including content presentation; students' knowledge, behavior, and engagement; and the classroom context in which work and learning occur. The academic work model assumes a cognitive view of students not as passive recipients of information but as active learners whose understanding and intellectual growth are shaped by the conceptual frameworks they bring to new information and by the operations they are required to do with content. Students' expectations about work that they will be held accountable for or tested on shape their attention and processing of information. This has been demonstrated in research on reading showing that subjects process

information in reading passages quite differently according to what they think their task is (McConkie, 1977). At a more general level, shaping of students' attention by their expectations of what will be on the test or what will be graded has been noted repeatedly (and often bemoaned) by observers of secondary classrooms. It is a reality of the classroom environment.

In summary, there is good reason to believe that student assignments are a key to understanding much of what happens in a secondary classroom. The nature of students' work and how it is handled by teachers affects what students attend to, how they process information, what skills they practice, how they are evaluated, and in the final analysis, what they learn. In the science classroom, studies of academic work provide a framework for examining functions, effects, and interrelationships of laboratory activities, discussions and questions, testing, and textbook assignments.

Definition of Task. In the Doyle (1983) model of academic tasks used in this study, a task is an assignment characterized by:

1) An end product such as answers on a worksheet, a written lab report, test paper or oral report.
2) A set of cognitive operations to produce the product. Students may have to copy a diagram of a cell, recall definitions, apply a given algorithm to solve a problem, or select and sequence several algorithms to solve a complex problem.
3) Resources available to students in completing the assignment. These may include a textbook, notes from a teacher presentation, peer assistance, models or examples, or answers announced in in class before the product is handed in. Note that class

discussions or teacher demonstrations or presentations usually function as resources for tasks, not tasks in themselves.

4) Some kind of accountability or expectation of accountability for work. Tasks are graded, checked, or inspected. They may result in a major or minor grade, extra credit, or a daily grade, or they may simply be turned in with the expectation that the teacher will inspect them.

The Teachers and Classes

The classes observed were first-year biology classes in two different schools within the same school district in the Southwest. Both classes were designated as honors sections, with a district-mandated curriculum focusing on development of higher level cognitive objectives. In Class 9 there were 20 students, including seven freshmen and 13 sophomores. Students' standardized achievement test scores from the previous year ranged from the 69th to the 99th percentile, with half of the students scoring at the 90th percentile or above. Class 10, while also designated an honors section, had a relatively heterogeneous composition. There were 24 students, including 11 freshmen, 12 sophomores and one junior. Students' standardized achievement test scores from the previous year ranged from below the 50th to the 99th percentile, with nine students having reading scores below the 75th percentile.

Both of the case study teachers were experienced teachers who had participated in the design of the honors curriculum for the school district. The following procedure was used in selecting the teachers. Nominations were solicited from the school district science curriculum coordinator, school prinicpals and the university coordinator of student

teaching in the area of science. Criteria that were suggested to the nominators included classroom management and organization competency, use of a variety of classroom tasks, including some addressing higher cognitive objectives, and general effectiveness in helping students achieve the school district's objectives for science education. Final selection was made by the research team after interviewing and observing classes of all teachers who were nominated by two of the three sources.

Data Collection and Analysis

Data sources included transcribed narratives based on observation of class sessions, copies of instructional materials, graded student work and transcripts of interviews with the teacher and selected students in each class. Each class was observed daily during the first week of the school term and during a six- (for Teacher 9) or seven- (for Teacher 10) week period during the teaching of the genetics unit. Each class session was observed and audiotaped by a trained member of the research staff with a science education background. The observer kept a running record of the sequence, timing and content of classroom events and circumstances affecting the work. These records included descriptions of teacher presentations and student participation, resources available to students, and teacher and student comments about assignments. Soon after each observation, the observer used observation notes and audio tapes of the class meeting to dictate for transcription a comprehensive narrative of the session.

Copies were obtained of all instructional materials and handouts used during the genetics units in each class. In addition, whenever possible, graded student products were collected and copied.

Both teachers were interviewed by one of the observers once at the beginning of the school term and again after the completion of the genetics unit. The teacher was asked about objectives and planning for the unit, the teacher's perceptions of teaching or learning difficulties relating to the genetics content and activities, information about grading or procedural aspects of the class, and the teachers' perceptions of degree of students' success on specific tasks. In addition, selected students representing a range of achievement levels and classroom participation styles were interviewed in each of the classes. In Class 9, nine students were interviewed once at the end of the genetics unit, concerning their perceptions and understanding of individual tasks, the work system and the genetics content. In Class 10, six students were interviewed on two occasions. The first interview at approximately the middle of the observation period focused on students' understanding of specific tasks that had been completed in the class up to that point. The second interview at the end of the observation period focused mainly on the independent research project completed during the study, but which was not part of the genetics unit.

Analysis. Analysis for the present study focused only on academic tasks related to the genetics content (in both classes students completed independent, experimental research projects and several other tasks that were observed but which are not included in this study). The first step in analysis was the identification and detailed description of tasks. Narrative data, instructional materials, student products, and teacher and student interviews were used to generate descriptive and analytical summaries of each task accomplished. These task descriptions were structured around the main characteristics of

tasks: task requirements, resources students used in accomplishing the work, accountability aspects, student performance and flow of events involving the task.

An objective of task analysis was to determine the cognitive demands of students' work, not only the demands as implied by the teacher's description of assignments, but also the apparent actual demands, in light of information about resources, accountability, student participation and events in the classroom. This gave us a clearer picture of what students were doing with the content, and what kind of practice opportunities they were receiving. Student understanding of the content was inferred from participation in the classroom, interactions among students during group work, inspection and item analysis of graded student assignments including tests, and task-focused interviews with selected students.

Another step in analysis was the identification of all major strands of content and the work associated with each. Content relationships and other connections across tasks were noted. The result was a map of how the genetics content was represented in assignments and activities in each class.

Results

The Genetics Unit in Class 10

Overview of tasks and content. A total of 26 tasks were completed in Class 10. Resource materials included the 1977 edition of Modern Biology (Otto & Towle, 1977); articles and diagrammatic sketches from various magazines and journals, including Science, Nature, and The Quarterly Journal of Microscopical Science; film loops, and teacher-made handouts, overhead transparencies, wall posters and work sheets. Table

1 summarizes and sequences the main strands of content with which students in Teacher 10's class worked, and Table 2 briefly describes the 26 tasks in the order in which they were completed. With some exceptions, Teacher 10 sequenced content roughly as it was presented in the chapters 7 through 11 of the Modern Biology text. Some of the text content was omitted, and the teacher supplemented the text explanations and activities to a large extent. Overall, a good deal of complex content was included in the unit as taught. Notable departures from the textbook sequences of content were related to a long term task, Task 22, a fruit fly experiment which students began early in the unit in order to have usable data by the end of the unit.

In general students in the class engaged in a variety of work, accomplished in whole class, small group and independent work settings. Most tasks were relatively short term, with one to three class sessions devoted to each. Engagement was usually high, and a great deal of work was accomplished in the class. Tasks were logically sequenced and designed so that several of the tasks required students to integrate content presented in previous work and instructional sessions.

Student work was usually introduced by teacher presentations of genetics content and procedures for carrying out laboratory activities. These presentations were instructional episodes in which the teacher explained concepts and demonstrated computational steps to be followed in solving problems, as in the determination of genotypic results of various matings. Teacher 10 questioned students frequently during these sessions, asking students to repeat information presented and to provide answers to problems as she worked examples on the board or transparencies. She also reviewed content by calling on students to

answer questions requiring application of procedures or content presented in previous sessions or previous tasks. Teacher 10 seemed to make a special effort to distribute response opportunities widely.

These instructional episodes were at times followed by small group activities that summarized or reviewed the content under discussion. One example of such an activity was group practice in sequentially ordering cards containing representations of cell division stages following a teacher presentation on mitosis. In another instance, students were required to work with partners to summarize the most important ideas of Gregor Mendel, following a teacher presentation of Mendel's experimental work with pea plants. The teacher then called on students from each group to provide summary ideas, and she elaborated on those given.

Each teacher presentation was followed by one to three minor related tasks such as homework, a quiz, or laboratory assignments. Of the 26 tasks, five included hands-on or laboratory experiences. For lab assignments, students were required to make observations, record data in sentence, paragraph or diagrammatic form, and at times to provide written answers to short essay questions concerning observations or conclusions. For example, one task (Task 24) required the determination of student characteristics concerning various traits (e.g., tongue curling and phenylthiocarbamide taste capabilities). Students were then required to determine their own potential genetic makeup for the given characteristics.

For the long term lab assignment (Task 22) students were required to set up and carry out monohybrid crosses with fruit flies, crossing a normal (wild type) female with a mutant male. Each lab team of two

students was assigned a particular mutant cross, without being told what the inheritance pattern for that mutation was. Observations were to have been recorded and inheritance patterns determined from experimental results. Once students figured out the probable inheritance pattern for their cross, observed results were to have been analyzed by use of Chi square to determine the fit of experimental with expected results, and potential sources of error were to have been identified by the students. Instruction and practice were provided students on use of the Chi square procedures, which were also included in the curriculum for this course because of an independent research project requirement.

Many of the tasks in this class required the integration of information presented in previous teacher presentations and tasks. Although exams were predominantly multiple choice and much of the assignments focused on recall of information, a significant portion of tasks also contained comprehension level components (items requiring other than simple recall or routine use of algorithms) to some degree. These included parts of all major exams and the fruit fly lab and at least half of the other minor tasks such as homework and quizzes.

Task Management and Effects on Student Work Experiences. Two aspects of task management in Class 10 seemed to have marked effects on student learning experiences. First, in the long term laboratory assignment, the fruit fly cross, procedural problems may have interfered with student learning, and extensive teacher assistance and prompting appeared to make it possible for many students to complete the assignment without understanding their work. This was a procedurally complex laboratory activity. Students were required to set up and carry out a two-generation monohybrid cross. They worked with partners to

determine dominant/recessive and chromosome linkage patterns from observational results. However, many flies died because of inappropriate handling techniques and food supply contamination. Experimental results in some instances were insufficient to determine appropriate inheritance patterns. Some groups had to start their crosses over or use results from other students' crosses. Throughout, many students received extensive peer and teacher assistance. The teacher expended a significant amount of time and energy in assisting individual students in the analysis of results, in response to student errors and requests for assistance. Nonetheless, student difficulties persisted and in many cases the cognitive demands of the task were reduced because the teacher provided much of the required problem solving for students.

Another consideration in Class 10 was that although the teacher provided a number of assignments to give students practice with genetics problems, the use of group work and in-class self-checking made it difficult for the teacher to monitor student understanding. For example, the first task containing dihybrid problems was completed in small group settings and only one paper was selected for grading from each group. During group work on this and other occasions, many students were observed copying answers from peers or simply requesting and receiving answers without explanatory interaction. On a subsequent task, students were required to solve a dihybrid problem independently. This problem, however, was identical to one from the previous task and could therefore have been answered at a memorization level alone. No other practice opportunities were provided with dihybrid problems. In other cases, homework assignments were checked for completion only, then

discussed in class before they were turned in for checking by the teacher. While this practice gave students feedback on their performance, it may have made it difficult for the teacher to assess individual student performance on practice assignments.

The Genetics Unit in Class 9

Overview of tasks and content. In the genetics unit in Class 9, students worked on 20 tasks including eight quizzes, three laboratory or hands-on activities in small group settings, and some independent practice assignments. Table 3 summarizes the tasks completed in this class. The content of several of the tasks was introduced to the students through the BSCS curriculum unit, Families: Living with cystic fibrosis, which this teacher was using for the first time as a framework for much of the class's work on genetics. Drawing on a large collection of resource materials, the teacher sequenced lectures, class work and homework, and quizzes around topics in the cystic fibrosis booklet. Thus, the content sequence shown for Class 9 in Table 1 is substantially different from that in the official course textbook, Modern Biology (Otto & Towle, 1971) and different from that used in Class 10. Other instructional materials included a variety of teacher-collected handouts, work sheets, film loops and films on probability, DNA structures and function, statistics, and cell reproduction. The textbook was used little--only one assignment was based on a textbook chapter and there were no other required reading assignments in the textbook.

Teacher 9 chose to use the BSCS unit because it presented genetics in a personal frame of reference, one that emphasized relevance of the content to students' lives. Other applications and genetics disorders--

hemophilia, Huntingdon's syndrome, genetic counseling and amniocentesis--were also discussed and reflected in students' assignments and quizzes. Thus, the meaning of this content for students' lives outside of class was emphasized throughout the unit.

Another characteristic of work in this class was that many tasks were reiterative. Some key content (basic principles and terms in Mendelian genetics, monohybrid cross problems) showed up on several successive tasks, especially quizzes. Testing, checking, and discussion of tests and retesting provided students with repetition and independent practice with some important genetics concepts. Unfortunately, not all concepts were emphasized in this manner, and examination of Table 3 will show that students in Class 9 actually completed very few practice tasks as homework or class work. Assigned practice tasks focused for the most part on DNA base pairing and coding and on statistics procedures. There were no practice assignments on dihybrid crosses or sex-linked trait problems. Such omission appeared to be related to the teacher's first-time use of the cystic fibrosis unit. In her interview, the teacher indicated that organization of work around the unit framework became difficult after the first week of the unit, and she was not satisfied with the small amount of work students did on some topics as a result.

Another problem observed in this class was that content presentations and discussions did not always provide students with well organized, clear explanations of content. In this class, classroom presentation and discussion usually preceded and sometimes followed relevant tasks. Students in the class were very vocal and classroom discussions were almost always very interactive and often unruly.

Interactions were often dominated by a group of five or six students, while a smaller number of students on whom the teacher could count most consistently for correct responses tended to be non-participants, except when called on. Teacher 9 commented during her interview that students in this class were unusually immature and undisciplined for an honors group and that pacing and controlling class discussion were difficult. Students asked many tangential questions or talked over the teacher, making clear exposition difficult. Consequently, time for systematic explanations and group practice with content was lost, and compared with students in Class 10, students in Class 9 experienced smaller amounts of organized direct instruction as well as fewer practice assignments with the genetics content.

Task management and effects on student work experiences. The manner in which Teacher 9 controlled task resources and accountability had some interesting effects on students' work experiences in this class. Unlike Class 10, work other than laboratory activities was limited to individual, not group, effort. However, like Teacher 10, Teacher 9 was forced to make some compromises in checking of students' daily work. Table 3 shows that often assignments were simply checked for completion before discussion in class. At other times, however, assignments were graded in class or by the teacher or pop quizzes were given over the content. Accountability was unpredictable and students appeared to assume that they would be held accountable for serious effort most of the time. Varying the accountability procedure for work but never completely suspending requirements for independent effort seemed to serve the purpose of keeping students accountable for

assignments, and in interviews Teacher 9 stated that that was her intention.

Use of effort (completion only) grades and the chaotic climate of classroom discussions appeared to make it difficult for Teacher 9 to assess individual student's understanding, except with content that was repeatedly included on quizzes. Even then, several circumstances suggest that students' performance on quizzes may have sometimes masked lack of understanding. First, some tests were open book/note, even when some of the content was at the recall level (terminology). Second, very similar or even identical problems were used on different tasks, so some answers could have been simply recalled or (in the case of open note tests) copied. Third, Teacher 9 often gave last-minute reviews of content immediately prior to a test. Emphasis in these somewhat rushed lessons was usually on specific procedures or facts students needed to know for the test. A procedural rather than comprehension-oriented approach was fostered by this practice.

For example, it has been noted that little content instruction and almost no practice was given to students on solving dihybrid problems. A four-page handout with clear explanation and examples was provided four days before the quiz as an optional activity, not to be graded, for students who didn't understand, but there was little evidence that students worked with this material. Immediately before the test, Task 25, the teacher told students to get out that handout and she quickly reviewed solution of dihybrid problems with Punnet squares and probability methods. She pointed out that there were 16 possible genotypes and stated twice the classic 9:3:3:1 ratio of phenotypes. Students then immediately took the test which had one problem featuring

a dihybrid cross with 16 offspring. This problem could have been easily answered with little understanding, by simply using the numbers 9, 3, 3, and 1. Only about half of the students showed their work using a Punnet square.

In summary, in Class 9 students' practice opportunities with genetics problems were limited, and content instruction was not always given very systematically and clearly. Some teacher practices seemed to have the effect of letting students get by with minimum understanding. However, repetitious quizzes on at least some of the content provided independent practice and feedback, and the teacher's approach to the genetics unit as a whole emphasized relevance and meaning.

Discussion

Our main purpose in examining the learning experiences students in these two classes had with genetics content was to come to a better understanding of the complexities science teachers face in conducting instruction and managing classroom tasks with secondary level content. This section summarizes our assessment of students' learning experiences and calls attention to three issues associated with limitations in their learning in these classes. Implications are noted for planning, conducting, and assessing science instruction.

Students in these two classes "successfully" engaged in a variety of carefully planned and articulated tasks with genetics content. They learned about genetics by doing and discussing a range of tasks, from simple observation and memory work to inference and complex problem solving. The curriculum they experienced extended beyond the textbook treatment of genetics, and comprehension and meaning were emphasized in

their work.There were logical relationships across tasks and between tasks and other aspects of instruction.

Nevertheless, interviews with students, analysis of student performance on quizzes, and students' interactions during class provide evidence that there was poor student understanding of concepts and procedures in several specific areas, including dihybrid cross problems, monohybrid problems involving sex linkage, rationales for statistical procedures in using Chi square and t-tests, and the significance of answers obtained with the the tests of significance. In addition, many students showed poor understanding of some of the tasks they engaged in. This was especially true of students in Class 10 in the laboratory task involving the fruit fly cross. Some students had misconceptions about terms used (e.g., wild flies and virgins). Others failed to grasp the purpose of the exercise and what it had to do with the rest of their work in genetics.

By examining classroom tasks and their relationship to other aspects of instruction, some sources of student difficulty were evident. First, in both classes there were instances of insufficient or unclear explanation of particular concepts or problem types. This was less true in Class 10 than in Class 9, where high levels of "static" and confusion sometimes interfered with discussions. Asking whether the teacher gave clear verbal explanations suggests an oversimplification, however. In classroom settings explanations may be repeated many times, to the whole class, small groups, or individuals. The cumulative effect of these varying reiterations on different individuals is difficult to assess. Further, the timing of presentations in relationship to work students attempt is another factor. The kind of timely, task-explicit

instruction that can be given in a tutoring session such as those used in the Stewart and Dale (1981) experiments is difficult to achieve in a whole-class setting. On the other hand, for high school students, teachers' verbal explanations are not the only sources of explanations. Written explanations in handouts, instructional materials or textbooks must also be considered, along with all other resources students are provided for classroom tasks. Some good explanations of content were provided in handouts by both teachers, although students in one of the classes were not always required to read and use these.

A second issue in both classes was the amount and quality of student practice tasks. Providing sufficient practice, monitoring students' performance, and giving corrective feedback are clearly problems in classroom settings in which there is a large amount of complex content to be dealt with. One of these teachers used peer group settings for students' working on problems and correcting them. Unfortunately, the quality of student interactions in the small group did not always provide individual students with accurate feedback or explanations. Group work also softened accountability for <u>independent</u> student effort and seemed to make it difficult for the teacher to know who understood the work and who did not. Sometimes quizzes were the first and only opportunities for students to work problems independently.

At other times the quality of students' learning experiences with the content was also affected by the amount of prompting and assistance students got from the teacher. In some cases, such as during the fruit fly experiment in Class 10 and in Class 9 when the teacher announced answers immediately before quizzes, teachers reduced the cognitive

demand of work significantly. Students were able to "get through" a task without actually doing the desired operations, much less understanding them. At least two areas are suggested for attention by those who would help teachers improve science instruction: management of cooperative work groups and strategies for checking and giving students feedback on their work.

A third issue illustrated in these cases is that of the difficulties teachers face in making wise choices of classroom tasks for different objectives. In that regard, a lesson can be learned from the experience of Teacher 10 and her students with the fruit fly experiment. That is, that combining complex operations and procedures (as in a complex laboratory experiment) with complex content may detract from student understanding of the content (see also the discussion of this point by Blumenfeld, Mergendoller & Swarthout, in press). Hands-on experiences can be valuable, but students may lose sight of or fail to focus on the meaning of concepts that are the reason for doing the laboratory activity. Thus, teachers need to decide when hands-on experiences can contribute best and when they may in fact get in the way of student learning. Simplifying procedures and manipulations for students may be warranted when students are working with new or complex concepts. One could argue that vicarious laboratory experiments such as those provided by inquiry film loops or slides or computer simulations might have resulted in better understanding for students in Class 10 than their actual participation in the long term, procedurally complex fruit fly experiment.

Conclusion

In conclusion, this case study of classroom tasks and instruction in two genetics classes illustrates how balancing demands of the secondary science curriculum and the classroom requires that teachers make careful choices in planning classroom tasks. The question they must answer is not simply, "Will this presentation contribute to this learning objective?", or even "Will this task contribute to this learning objective?" But, "Will this task conducted in this way contribute to this learning objective for these students?" To answer the second question, teachers must focus on what students actually do and are held accountable for in the classroom.

Table 1

Sequence of Task Content in Two Classrooms

	Teacher 9	Teacher 10
Begin Unit	Genetic disorders: cystic fibrosis	DNA structure and role in protein systhesis.
	Probability and its relationship to inheritance mechanisms.	Sex differences in Drosophila and procedures for Drosophila cross.
	Mendelian genetics, terminology.	Genetics mutations.
	Monohybrid pedigree problems.	Mitosis processes.
	Sex-linked trait inheritance.	Meiosis processes.
	Karyotyping.	Mendelian genetics, terminology and history.
	DNA structure and role in protein synthesis.	Genetic vs. environmental influences on humans.
	Other examples of human genetics disorders: Hemophilia, Huntingdon's Disease, Sickle Cell Anemia.	Monohybrid pedigree problems.
		Dihybrid pedigree problems and incomplete dominance.
	Dihybrid pedigree problems.	Sex-linked trait inheritance.
	Chi Square procedures and use in evaluating experimental results.	Probability and its relationship to inheritance mechanisms.
	T-test procedures and use in evaluating experimental results.	Chi Square procedures and use in evaluating experimental results.
	Mitosis processes.	Interpretation of Drosophila cross results.
	Sexual vs. asexual reproduction.	Inheritance patterns: Multiple alleles (eye color).
End Unit	Meiosis processes.	Genetic disorders.

Table 2

Summary of Genetics Unit Tasks Accomplished in Teacher 10's Class

Task Number: Major/Minor	Description/Content Covered	Management Notes/Student Success
1. Minor	Worksheet. 12 short-answer and fill-in-the-blank questions concerning the structure and replication of DNA. Mostly memory, some comprehension questions. Homework assignment.	Work checked by teacher for completion only on due date. Students permitted to correct answers for full credit during in-class checking of work.
2. Minor	Lab activity. Observation and summary in chart form of five differences between the male and female fruit fly. Mostly memory, some translation of observations into written descriptions.	Students worked in pairs. Products were collected and checked by the teacher. 25% of Ss received 0-2 of the total 5 points possible. No grades recorded in teacher's grade book.
3. Minor	Quiz. One question over a homework textbook reading assignment on transcription/protein synthesis, "What is the role of ribosomes in protein synthesis?" Memory level.	Work collected and checked by the teacher. 50% of the students received zeros for their work.
4. Minor	Worksheet. 7 fill-in-the-blank and matching-type questions over the structure/replication of DNA, and transcription/protein synthesis. Memory- and procedure-level operations (i.e., symbolic translation of DNA segment representations into amino acid chains.) Homework assignment.	Students permitted to correct answers for full credit during in-class checking of work.
5. Major	Exam. 29 multiple-choice, fill-in-the-blank, and short-answer questions on the structure/replication of DNA, and transcription/protein synthesis. Mostly memory, some comprehension questions.	Checked by teacher. Students received "automatic" points equal to 4% of the task grade.
6. Minor	Worksheet. 16 short-answer and fill-in-the-blank questions concerning chromosome structure and cell division (mitosis). Memory level. Homework assignment.	Students permitted to correct answers for full credit during in-class checking of work.

Table 2, continued

Task Number: Major/Minor	Description/Content Covered	Management Notes/Student Success
7. Minor	Lab exam. Students were required to identify the sex of three fruit flies from microscopic observation. Memory level.	Students who did poorly were permitted to retake the exam for full credit.
8. Minor	Worksheet. 16 short-answer and fill-in-the-blank questions concerning gamete formation (meiosis) and fertilization. Memory level. Homework assignment.	In-class checking of work but no grades recorded in the teacher's grade book.
9. Minor	Lab activity. Observation/identification/diagrammatic representation of mitotic stages in onion root tip slides. (Slides observed, stages drawn, and cell parts labeled.) Also included three related short-answer questions over the content. Required the recognition of division stages in tissue specimens from diagrammatic representations.	Students worked in pairs. Products were collected and checked by the teacher.
10. Minor	Quiz. 15 multiple-choice, fill-in-the-blank and short-answer questions concerning cell division (mitosis), and gamete formation (meiosis)/fertilization. Mostly memory, some comprehension questions.	Students permitted to correct answers for full credit during in-class checking of work.
11. Minor	Worksheet. 8 short-answer questions over gamete formation (meiosis) and fertilization; laws of segregation and independent assortment. Comprehension level. Homework assignment.	Work collected and checked by the teacher.
12. Major	Exam. 37 multiple-choice, matching, fill-in-the-blank, and short-answer questions concerning cell division (mitosis), and gamete formation (meiosis); laws of segregation and independent assortment. Combination of memory and comprehension questions.	Students received "automatic" points equal to 4% of the task grade. 25% of the students received failing grades (less than 70 of the 100 possible points received).
13. Minor	Quiz. 5 short-answer questions concerning genetics terminology and Mendel's contribution to the field of biology. Memory level.	Work collected and checked by the teacher. The majority of the students received less than 20% of the total points possible.

Table 2, continued

Task Number: Major/Minor	Description/Content Covered	Management Notes/Student Success
14. Minor	Quiz. 8 multiple-choice questions concerning genetics terms and concepts including gamete formation (meiosis)/fertilization, laws of segregation and independent assortment, and principles of gene dominance/recessiveness. Memory level.	Work collected and checked by the teacher. 25% of the students received failing grades (4-6 of a possible 10 points).
15. Minor	Worksheet. 13 monohybrid genetics problems. Expected genotypic and phenotypic ratios for each of the crosses. Comprehension and Procedural operations. Homework assignment/Classwork.	Individual and group work. Teacher formed problem-solving groups of 3 to 4 students each. Ss corrected their papers within groups, discussing and explaining work as they did so. Papers were collected from one member of each group. All students received the same grade. 2 points extra credit given to groups with completed work. 15 point assignment. No students received less than 15 points.
16. Minor	Worksheet. 5 dihybrid genetics problems. Determination of expected geno- and phenotypic ratios. Comprehension and procedural (algorithic) operations. Homework assignment/ Classwork.	Students worked in problem-solving groups, correcting problems after they were completed as homework assignments, as in #15 above. Group accountability. 2 points extra credit given to groups with completed work. Products collected from one member of each group. 25% of the students received failing grades (0-6 of 10 possible points).
17. Minor	Quiz. Solving of one dihybrid genetics problem. Determination of expected phenotypes. Comprehension- and procedural (algorithmic)-level operations.	Independent work but students lost 1 point from this unannounced quiz (total 10 points) if all members of their problem-solving group did not do it correctly. Some student/student private interactions during testing time.
18. Major	Exam. 14 multiple-choice and short-answer questions on an exam including the solving of mono- and dihybrid genetics problems. Determination of geno- and phenotypic outcomes. Comprehension- and procedural (algorithmic)-level operations.	Work collected and checked by the teacher.

Table 2, continued

Task Number: Major/Minor	Description/Content Covered	Management Notes/Student Success
19. Minor	Worksheet. 6 monohybrid genetics problems involving sex-linked traits. Determination of expected genotypic and phenotypic ratios and corresponding sex distinctions for each cross. Comprehension- and procedural (algorithmic)-level operations. Homework assignment/ Classwork.	Students completed work individually as homework and then corrected answers in their problem-solving groups on the following day as in #15 and 16. Extra-credit points (2) to group members in all groups with completed assignments from each member. Some teacher/group interactions during work.
20. Minor	Quiz. One question over a textbook reading assignment done for homework on human genetics, "How is eye color inherited?" Memory level.	Products were collected and checked by the teacher but no grades recorded in the grade book.
21. Minor	Worksheet. 2 problems involving the analysis of given results of monohybrid crosses in terms of chi square and probability values. Procedural- and some comprehensiion-level operations. Homework assignment/Classwork.	Students worked individually or in groups. Products were collected, checked and returned to students to be corrected. Teacher provided further content instruction and students re-did products wtih group members. Revised products collected several days later, no grade penalty. 25% of Ss received failing grades (less than 70% of total points possible answered correctly).
22. Major	Lab activity. Long term (7 week) task: Mating of wild type and mutant fruit flies. Students were to keep records of various characteristics as found in the F_1 and F_2 generations and determine probable inheritance patterns for the traits used in their crosses according to experimental results obtained. Ss determined the fit of experimental with expected results by use of Chi Square analysis. All data and analysis were to have been written up in a lab report. Comprehension and procedural level operations.	Students worked in pairs. Teacher instruction on requirements, form, genetics content, and statistical procedures. Individual and group assistance provided. Work in progress was collected periodically and feedback given for revisions. Many procedural difficulties and extensive prompting and assisting by the teacher were noted.

Table 2, continued

Task Number: Major/Minor	Description/Content Covered	Management Notes/Student Success
23. Minor	Homework assignment. 6 short-answer discussion questions over a magazine article on environmental vs. genetic influences on physiological/psychological characteristics in humans. Memory level.	Students worked on this first as homework assignment and then later permitted to work in groups of 3 to 4 to complete it. No grade was recorded in the teacher's grade book for this task.
24. Minor	Lab activity. Determination of students' phenotypes for a variety of traits. Ss were to test themselves for the traits, record results in chart form, and determine possible gene combinations for each of the traits. Family pedigrees for any three of the traits could be done for extra credit. Some comprehension- and procedural (algorithmic)-level operations.	Students worked in pairs. Work collected and checked by the teacher. Over a third of the students reecieved failing grades; most of these students had not completed and handed in the work.
25. Major	Exam. 44 multiple-choice, matching, and short-answer questions concerning most of the genetics content from the unit; gamete formation/fertilization, principles of gene dominance/recessiveness, sex chromosome linkage, laws of segregation and independent assortment, Punnett square methods for determining genotypic and phenotypic results of mono- and dihybrid crosses, inheritance patterns, statistical analysis of experimental results, and environment vs. genetic influences. Comprehension to memory level.	Teacher provided a brief review of probability problem solving immediately before the test. Many teacher/student and some student/student interactions took place during testing time.
* Major	Independent research project. Students design, conduct, analyze, and report (written) experimental study. 18-week project, mostly outside of class time.	Self-paced task. Teacher provided instruction and practice on requirements, form, statistical procedures, research design. Teacher gave individual assistance and resources. Work in progress was collected periodically, and feedback given for revisions. Major grade.

* This task was not directly related to content of the genetics unit but was worked on during the unit. Also, content instruction and tasks on statistics contributed to this task.

Table 3

Summary of Genetics Unit Tasks Accomplished in Teacher 9's Class

Task Number: Major/Minor	Task Description/Content Covered	Management Notes/Student Performance
1. Major	Exam on genetics terminology, probability, and pedigree problems. 25 matching and multiple-choice questions. Recall-, procedural (algorithmic)-, and comprehension-level questions.	Open-book/notes. Teacher reviewed terms/definitions immediately before test. Some private and public prompts during work. Graded in class. Two-fifths of points were recognition of terms, three-fifths for problem solving. No extra credit.
2. Minor	Lab activity on probability: One- and two-penny toss. Procedures, recording data, answering questions, inference of probability principles. Comprehension- and procedural-level operations.	Group work, peer assistance. Some individual teacher and aide assistance with questions. At end of period teacher led discussion/recitation over questions. No grades taken.
7. Minor	Lab activity on tobacco seed germination. Students planted seeds, recorded ratio of green to albino seedlings, and determined dominant/recessive patterns according to observed results for entire class. Procedures and some comprehension-level requirements.	Students worked in pairs and periodically checked growth of seeds. A lot of group socializing during work periods. Teacher gave Ss procedural assistance to begin the work and a computer summary of class data. Teacher led class in analyzing data with Chi Square as practice for test. Lab sheet never taken up or graded.
8. Minor	Homework assignment on karyotyping, mostly cutting and pasting of chromosome representations. Visual matching of similar chromosomes.	Teacher had students hold up their work for her to see. She later checked this assignment when notebooks were collected. Many of the Ss had not originally completed the task.
9. Minor	Classwork/Homework Assignment. 20 short-answer questions on structure and function of DNA and a paper model construction. Mostly recall-level questions with some minor comprehension of the significance of given experimental results and procedural operations. Necessary content explained on the handout.	Graded for completion only. Due date extended 1 day.
11. Minor	Notebook check. Teacher checked notebook for Task 8 (above) and organization, completeness.	Maximum 10 points. Grades ranged from 7-10. No discussion.

Table 3, continued

Task Number: Major/Minor		Task Description/Content Covered	Management Notes/Student Performance
12	Minor	Homework assignment on six-finger pedigree. Given complex story partly describing incidence of six fingers in several generations of large family, students prepare two possible pedigrees, assuming dominant, then recessive trait. Procedural (algorithmic)- and comprehension-level.	Independent work. Some individual teacher assistance. Effort grade only. Students received full credit for any attempt at two pedigrees, part credit for one.
13.	Major	Mendelian genetics quiz. 17 multiple-choice questions pedigree problems, domianant/recessive patterns, geno- and phenotypic results of crosses (monohybrid), and probabiltiy principles. Comprehension and procedural (algorithmic) level.	Open-book/notes. No teacher assistance. Six students (of 19) failed.
14.	Minor	DNA quiz. 11 recall-level questions over DNA structure, covering lecture and Task 9 handouts.	Closed-notes test, 22 points. graded in class. Teacher reviewed facts immediately before test.
15.	Minor	Pop quiz on Huntingdon's Disease inheritance and Punnett Squares. Mostly memory, some comprehension questions.	Graded in class. Only perfect papers collected and these counted as extra credit assignment.
16.	Minor	Homework worksheet. Students work DNA transcription and translation problems to determine protein's coding for hypothetical characteristics of an imaginary "monster" then they draw the monster as coded. Procedural level.	Students worked independently. Checked for completion of drawing only, credit/no credit. Best monsters displayed on wall.
17.	Major	Test on DNA and pedigree problems. 31 multiple-choice, short-answer questions on DNA structure/function, probability principles, pedigree problems (mono- and dihybrid). About half recall-, half comprehension- and procedural-level questions.	Students had no previous experience with dihybrid problems. Many resources for rest of content provided prior to test. 2 days in-class review. 12 minutes of directly-related instruction immediately preceding test. Some content very similar to Task 13. Some private teacher assistance during test. Scoring heavily weighted toward memory-level items. All Ss attempting dihybrid problem (worth 10 of 100 points) received at least part credit.

Table 3, continued

Task Number: Major/Minor		Task Description/Content Covered	Management Notes/Student Performance
18.	Minor	Classwork/homework: DNA worksheet. Students decode base triplets to read a message. Procedural. Time filler.	Picked up. No information on grading.
19.	Minor	Laboratory activity on Mitosis. Students examine prepared slides of onion and white fish cells; draw and label using text or handout diagrams; answer four recall-level questions.	Group work, 2 days, finished as homework. Many late or poorly done papers. Graded by teacher. Failing students allowed to resubmit. Lab pairs assigned by teacher. Assistance by teacher and aide.
21.	Minor	Chi Square Homework Assignment. Students analyze given experimental results by Chi Square. Application of algorithm and some interpretation required.	Checked in class (trade papers; use transparency). Turned in for five-point grade. Preceded by similar assignment day before which was announced as a task, but used only as practiced and reviewed in class. Only four students got fewer than four of five points, although only three Ss in class got and interpreted the answer correctly.
22.	Minor	Homework assignment: Cell division worksheet. 32 short-answer questions on cell structure/division (Mitosis/Meiosis). Recall level.	Checked for completion only. Six students turned it in late.
23.	Minor	Quiz on Mitosis/Meiosis. Given diagrams of cells undergoing Mitosis or Meiosis, students identify stages and structures. Recall level.	14 minutes of content instruction/review given immediately before test, in response to student requests. One diagram on test was duplicate of that used in lab and study material. Most grades were high.
24.	Minor	Homework assignment. Students compute two Chi Square problems and one t-test on experimental data presented in story form. Procedural (algorithmic) and some comprehension level.	Papers checked for completion only, then students corrected their own work during teacher presentation. Poor student comprehension evident during noisy review.

Table 3, continued

Task Number: Major/Minor		Task Description/Content Covered	Management Notes/Student Performance
25.	Major	Quiz on genetics problems and statistics. Solving of mono- and polyhybrid genetics problems. Determination of geno- and phenotypic outcomes. Analyze experimental results by use of t-tests (one problem) and Chi Square (one problem). Recall, procedural, and some comprehension level.	One monohybrid problem was exact duplicate of problem on preceding test. Direct content instruction on dihybrids given immediately before test. Also brief instruction on Chi Square. Tables and formulas provided. Two novel problems treated as extra credit. Some private assistance from teacher during test.
27.	Minor	Pop quiz over homework reading assignment on population genetics. Recall- and comprehension-level questions.	Announced as extra credit but mandatory participation. Papers graded in class and discussed. No information on student performance.
*3.	Minor	Independent project. Wide variety of student tasks or experiences outside of class: Field trips, watch biology TV programs, write short reports, prepare bulletin board displays, serve as lab aide, posters or models. Brief report or documentation turned in each 6 weeks.	Student choice of project within limits. Counted 5% of 6-weeks grade. Due dates extended. Little class discussion. Graded as check plus or minus.
*4.	Major	Independent research project. Students design, conduct, analyze, and report (written) and experimental study. 18-week project, mostly out of class. Comprehension and procedural (algorithmic) level.	Instruction on requirements, form, statistics. Teacher provided models, resources, individual assistance, and feedback. Self-paced accountability system. Students submit parts and sequence; receive mark of accept or revise, with feedback, no penalty. Failure warnings to parents of students not making progress.
*5.	Minor	Current reading assignments. Four written reports on articles concerning current science topics bibliography provided. Students summarize contents and comment on content. Low-level comprehension.	Teacher provided current magazines with articles on science topics for student use, but students mostly used out-of-class resources including newspapers. Not graded on sentence structure or writing skills.

* These tasks were not directly related to content of the genetics unit, but were worked on during the class. Also, content instruction and tasks on statistics contributed to Task 4.

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